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LUMINARY Memo #148

To: Distribution
From: B. McCoy
Date: 11 May 1970
Subject: Call It LUMINARY 1D

Revision 163 of Luminary was released on 5/5/70 for manufacture. It contained a total of 39 PCRs, 6 PCNs, 15 ACBs and 6 Anomalies. On the following pages is a detailed description of each implementation or a reference made where appropriate.

The following is a list of the Fixed Memory changes showing the total number left of words in each bank.

| <u>Bank No.</u> | <u>1C</u> | <u>1D</u> | <u>Bank No.</u> | <u>1C</u> | <u>1D</u> |
|-----------------|-----------|-----------|-----------------|-----------|-----------|
| 0 | 2 | 2 | 22 | 4 | 5 |
| 1 | 0 | 2 | 23 | 6 | 3 |
| 2 | 10 | 1 | 24 | 0 | 17 |
| 3 | 14 | 14 | 25 | 16 | 3 |
| 4 | 24 | 2 | 26 | 2 | 0 |
| 5 | 3 | 0 | 27 | 4 | 0 |
| 6 | 5 | 5 | 30 | 9 | 15 |
| 7 | 12 | 1 | 31 | 5 | 6 |
| 10 | 1 | 1 | 32 | 0 | 94 |
| 11 | 3 | 3 | 33 | 6 | 174 |
| 12 | 4 | 4 | 34 | 57 | 131 |
| 13 | 15 | 15 | 35 | 33 | 33 |
| 14 | 2 | 2 | 36 | 6 | 10 |
| 15 | 15 | 21 | 37 | 6 | 4 |
| 16 | 1 | 2 | 40 | 17 | 3 |
| 17 | 0 | 0 | 41 | 23 | 18 |
| 20 | 0 | 0 | 42 | 7 | 7 |
| 21 | 0 | 13 | 43 | 1 | 5 |

total 1C remaining 313

total 1D remaining 616

PCR/PCN

IMPLEMENTATION/COMMENTS

- 286 RLS and TLAND were placed in sequence for V71 uplink format. RLS begins at E4, 1420 and TLAND begins at E4, 1426. AGSK moved to E6, 1771 and VELBIAS is now at E5, 1400.
- 287/1038 The 526 alarm (Range to CSM > 400 N. M.) was deleted from P22. Instead V16N54 is displayed (range, range rate, θ) if the range rate is negative. If the range is greater than 400 N. M. and the range rate is positive in P22, a flashing Verb 37 results. In P20, if the range is greater than 400 N. M. the alarm light is turned on with code 526 stored. The range and range rate values for Noun 54 are computed and stored for possible monitoring by a V16N54 request from the crew. See memos #133, 133 rev 1, "Implementation of PCR 287" by P. Volante, V. Dunbar.
- 294 The quantity HIDESCENT was increased to 16,700 kg for the heavier LMs.
- 296 In P68, GSAVE (the 'G' vector saved for gravity measurements in P57) is the unit vector of RN (post landing navigated state vector) in Nav Base coordinates.
- 298 LR position change will now give a 523 alarm after 10 seconds if antenna did not reach position #2. Instruction change was simply CAF FOURTEEN to CAF FOUR. Also see Luminary Memo #146 "The New R12" by R. Covelli. (also PCR 1022)
- 306 DVTOTAL, the accumulated Delta Velocity during Average-G, was placed in word 78 of the Descent/Ascent Downlist.
- 307 TSIGHT, the AOT Marktime, was placed in word 99 of the Lunar Surface Align Downlist; CURSOR was placed in 100A and SPIRAL in 100B.

- 310 Coding was introduced to inhibit the 511 alarm until the antenna has been out of the desired position 5 consecutive passes through SERVICER (10 seconds). A counter (511CTR) is set to four when the antenna is first detected out of either position (or in both positions simultaneously) and it is decremented every succeeding pass the antenna remains out of position. Its location is E7, 1622. (See PCR 1022)
- 314 The Guidance Thrust Command is time associated with a particular PIPTIME. GTC and GTCTIME are in the same "snapshot" on the Descent/Ascent downlist and located in words 5a and 6a/6b respectively. GTCTIME is E7, 1752.
- 315.2 A new channel (77) was created to serve as a Hardware Restart indicator. It replaced CADRFLASH +1 in all Downlists. The first half of the word (channel 76) is a spare.
- 821.2 AZO is the angle between the x-axis of the Basic Reference Coordinate System and the x-axis of the Earth-Fixed Coordinate System at July 1, 1969. It was placed into fixed memory since it remains essentially the same for a given year.
- 872.4 A TIG countdown is started prior to the attitude maneuver in P41. It continues until TIG -35. A job, DYNMDISP, is scheduled immediately after P41 is called; it computes TFI and then calls itself every second. P41 proceeds on with DYNMDISP in the background, like CLOCKTASK in P40, 42. If V16N40E is used to monitor TFI, then V16N85E must be keyed if the VG display is desired again.
- 874.2 As in Colossus the astronaut does not have to key leading zeroes to a decimal load. For example a decimal load of +50 will reappear as +00050; +E will reappear as +00000E.

- 892 R29, the Ascent RR Designate Routine, was deleted from Luminary.
- 896 In an effort to save valuable time during the Powered Descent, the LR velocity readings are centered around PIPTIME. For details see Luminary Memo #146 "The New R12" by R. Covelli. The Radar Read routine used by the LR & RR was rewritten.
- 897 PCR 775 provided the capability to compensate for a Hardware failure in the Doppler Ranging Unit of the Landing Radar, a precautionary measure. This coding was removed.
- 898 In Luminary 1B the LR velocity readings were not taken until the S/C Inertial Velocity was 2000 fps. In Luminary 1C this limit was changed to 6000 fps, effectively removed. In Luminary 1D it was removed entirely, so that now LR velocity readings will start as soon as the velocity data good appears after R12 begins. Also see Luminary memo #146 "The New R12" by R. Covelli.
- 899 Erasable "TET" (N38) which is the time to which state vector is being integrated in each time step was put on the following downlists: Coast and Align, Lunar Surface Align and Rendezvous/Prethrust. It could aid the ground controllers to detect integration loops.
- 942 A value of 50 ft (scaled meters B-10) was placed into fixed memory; LR updates are inhibited below this altitude. This number (HLROFFF - Single Precision) is loaded into the least significant half of a Double Precision word (HLROFF) at the start of P63 (FLAGORGY); therefore, HLROFF can be externally changed to a different value after P63 is called. In routine MUNRETURN, HCALC (most significant half) is check to see if it is < 3000 ft (bit 1 = 0). If so,

HCALC +1 (least significant half) is subtracted from HLROFF. A plus result will reset LRINHFLG (flagword 11 bit 8). Later in the position update (NOREASON) and also in the velocity update (VUPDAT) this bit is checked. If it is reset, SERVICER continues without any LR updates (effectively a V58). HLROFF is E7, 1451.

944 LATVEL and FORVEL, the cross pointer lateral & forward velocity, are now on the Descent/ascent downlist in word 12, in that order.

945 In Flagword 11, bits 13 and 14 will now be set to indicate when at least one failure of the Altitude and Velocity Reasonability tests respectively have occurred. They are reset whenever their respective reasonability tests are passed.

970.2 Recently built gyros have a large bias shift that is dependent upon the polarity of the last torquing on the gyro. Coding was added to the IMU Pulse torquing routine to eliminate this bias shift. For details call R. Lones at MIT 864-6900 X821-529.

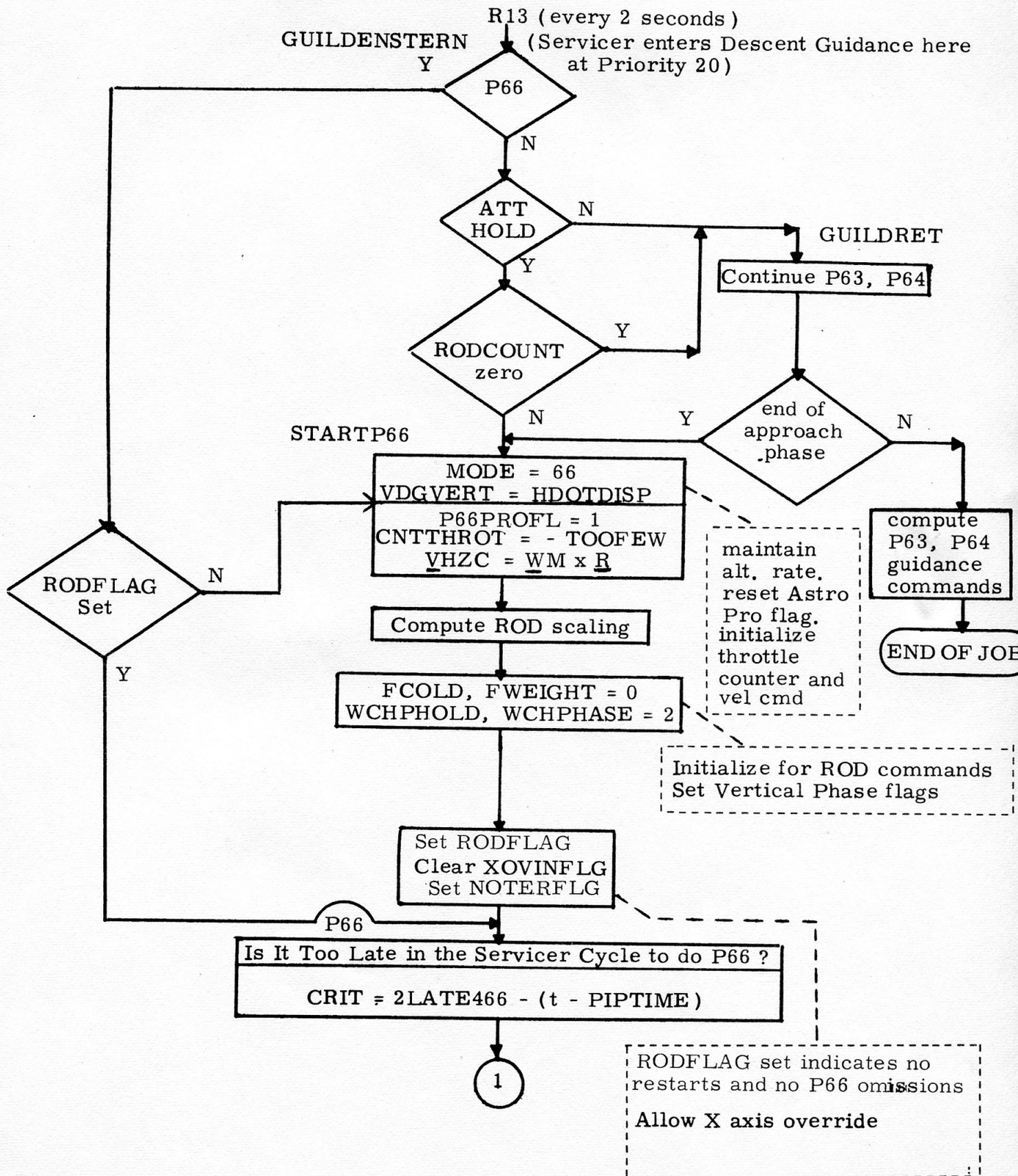
979 Program alarm 521 was a redundant indication of RR data good loss, so it was removed.

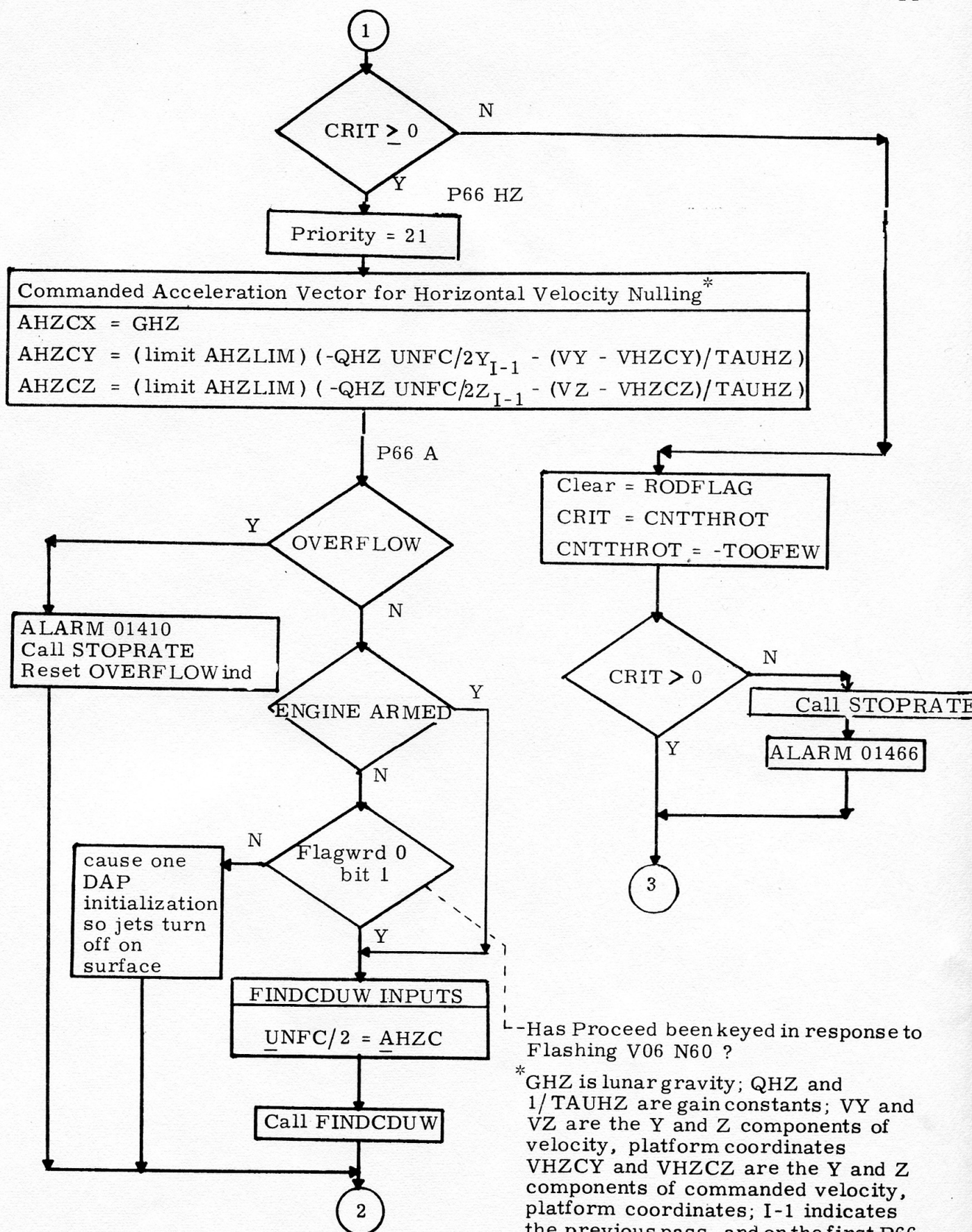
982 For Lunar Surface Alignments, Cursor/Spiral angles are now available for all celestial bodies, not just catalogued stars. Thus any body specified by N88 will be accompanied by a N79 display. The setting up of BESTI and the check for a catalog star were removed. Routine PLANET now interrogates N70 (R1).

- 983 N88 will now accept unit vectors instead of the half unit vector. Prior to unitizing, N88 (location STARAD) is divided by $(3)^{-1/2}$ to insure the unit operation will not overflow.
- 986.2 Fixed Memory Ephemeris constants were updated to 1970-1971 year.
- 988/1037/1035 P66 is essentially the same as it was in Luminary 1C (LM131 rev 1) which was done so as to keep changes only in one rope module for the re-release of Luminary 1C. Differences: a PRO to the V06N60 sets P66PROFL (Flagwrd 0, bit 1). This inhibits FINDCDU from sending RCS commands if the ENGARM switch is off. PCN 1037 removes a "Stoprate" and the resetting of REDFLAG (Flagwrd 6 bit 6) from P66 initialization. It also adds a "Stoprate" when a 01466 alarm occurs. Therefore should the situation arise via high TLOSS etc, that P66 is having difficulty in emitting sufficient throttle commands, a 1466 alarm will occur preceded by RCS jet activity to stop any vehicle rates. PCN 1035. The Terrain Model will be terminated when P66 is started; NOTERFLG (Flagwrd 1, bit 11) is set which causes Servicer to bypass Terrain Model computations.
- 990 Fixes Anomaly L-1C-04. A one second cycle was set up in V44 logic to wait for a Remode to be completed (checks bit 14 of RADMODES) before terminating a continuous designation of the RR.
- 991.2 The UPRUPT routine interrogates NODOP07BIT (Flag 3 bit 11) which is set by any V37EXXE after earth launch. If it is "0" the Uplink telemetry code (KEYTEMP1) is added to the previous summation of codes and forms a new sum (UPSUM). Next a counter (located at UPSUM +1) is

incremented to show the total number of uplink codes received. If NODOP07BIT is "1" no summing takes place.

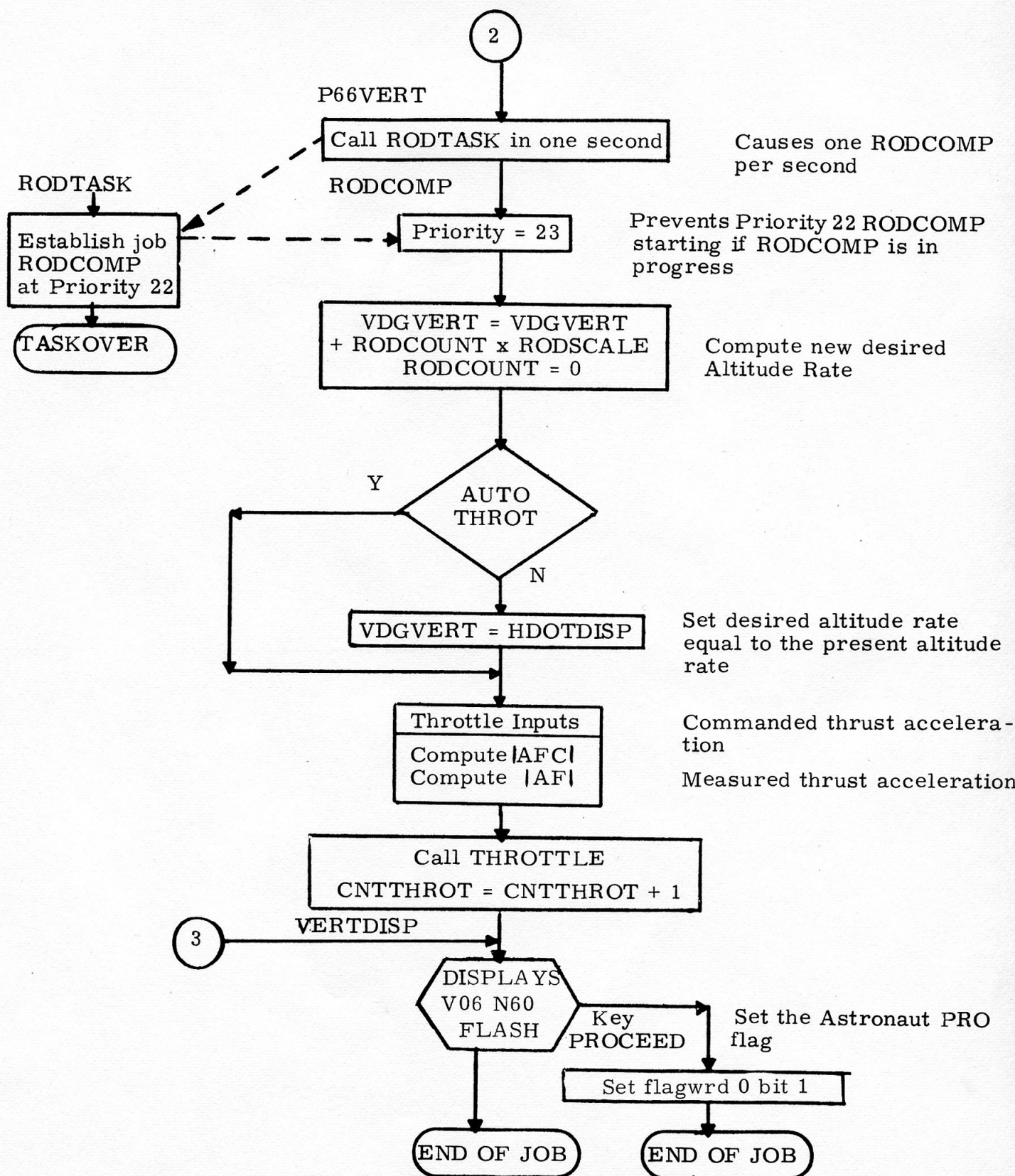
UPSUM, UPSUM +1 share with ABDELV, location 1245.





--Has Proceed been keyed in response to
Flashing V06 N60 ?

* GHZ is lunar gravity; QHZ and $1/\text{TAUHZ}$ are gain constants; VY and VZ are the Y and Z components of velocity, platform coordinates VHZCY and VHZCZ are the Y and Z components of commanded velocity, platform coordinates; I-1 indicates the previous pass, and on the first P66 pass this indicates the final P64 pass. (LIMIT AHZLIM) indicates the content of the subsequent parentheses is magnitude limited to AHZLIM.



996/1036

The selection of P07 (V92) is now contingent on NODOP07BIT (Flag 3 bit 11) being "0". If it is "1" the Operator Error light is illuminated. A Fresh Start will not disturb this bit so that V36 can be used to terminate P07; therefore, P07 can be called again without manually resetting NODOP07BIT. However, if V37 is used, e.g. Sim Flights before launch, the bit must be reset before P07 can be called.

1013

was implemented into LUMINARY 1D essentially the same as for LUMINARY 1C. It assures against stacking of jobs when TLOSS is present by omitting one horizontal and two vertical P66 commands. If there are too few vertical commands for proper ROD control, alarm 01466 is given. See Luminary Memo #~~142~~¹⁴³ "Automatic P66" by Allan Klumpp.

1015

Immediately on keying V90E, V37FLBIT bit is checked to see if Average G is on. If so, the Operator Error light is illuminated.

1021

now has precomputed LR position transformation matrices in Fixed Memory (VZBEAMNB) eliminating the computation time and to facilitate coding of PCR 1022. Routine POSINDEX sets the Interpreter Index Register X1 in accordance with the LR Position (location LRPOS):
Position 1 - LRPOS = 2 , X1 = -24D , X2 = 0
Position 2 - LRPOS = 1 , X1 = 0 , X2 = 0
Thus, when POSUPDAT and VELUPDAT routines use the LR measurement data, it is transformed in accordance with X1 from NB to SM coordinates. Four padloads were deleted: LRALPHA, LRALPHA2, LRBETA1, LRBETA2. Also see Luminary Memo #146 "The New R12" by R. Covelli.

1022

The handling of the LR position alarm has been made very simple. In R12 channel 33 bits 6 and 7 are checked to see if there had been a change in position from the previous Servicer pass. If both or neither position discretes are present Servicer continues without any LR updates (Terrain model also bypassed). If this situation exists for 5 passes (10 seconds) 511 alarm is given and will be given once every 10 seconds until the situation is corrected.

If either position 1 or 2 discretes are present it is checked against the present position (indicated by LRPOS). If they are different, Servicer continues with no updates. If they are the same, updates may be performed. Routine HIGATJOB is called to reposition the LR to position #2 at the beginning of the approach phase (P64). After the antenna has reached position #2 or after 10 seconds, "LRPOS" is set equal to 1 to indicate (reverse logic) that the new position is to be 2. If the antenna did not reach position #2, the 511 alarm will be given as described above. If the position is #2, normal updating continues. Note: the 523 alarm has been eliminated from R12 although it still exists for V59.

1025

The LM navigated state vector was updated for any gravity effects on altitude after the LR updates. This was deemed to be insignificant and was removed. A call to MUNGRAV was removed from routine RVBOTH.

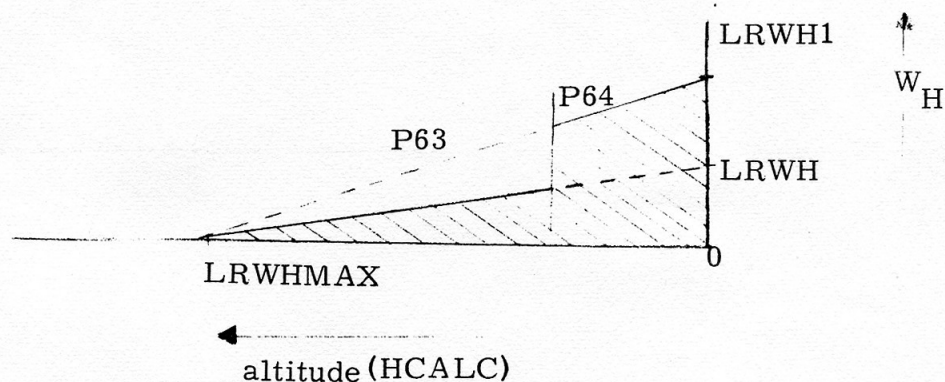
1027/1035

An a priori Terrain Model was implemented into Luminary to smooth the trajectory over rugged lunar terrain and to reduce the LPD errors and fuel consumption. It uses 5 segments, a slope and a range-to-landing site (abscissae), for each. The terrain not falling into the segmented region

(the model covers a region from some specified abscissae (range) to the landing site) will be modelled by a constant altitude, equal to the altitude at the last abscissae. The slopes and abscissae are specified in E memory by SLOPE0, 1, 2, 3, 4 and ABSC0, 1, 2, 3, 4. SLOPE~~4~~ and ABSC~~4~~ correspond to the segment nearest the landing site (loc E5, 1527 and E5, 1522 respectively, scaled B-6 and B-18 respectively). For more details see Luminary Memo # by Allan Klumpp, Don Eyles, and Bruce McCoy. 147

1028/1039

A new padload (LRWH1, E7, 1756) was created to allow for a two-segmented altitude weighting function. The present scheme is as shown below.



given by equation $W_H = LRWH (1 - HCALC/LRWHMAX)$.

LRWH is set equal to LRWH1 in P64.

W_H is altitude weighting function.

LRWH, LRWH1, and LRWHMAX are erasable to set the slope. HCALC estimated altitude.

1029

Due to the extensive analysis done prior to Apollo 13 on TLOSS it was found that the ground controllers could possibly determine what percentage of the computer duty cycle was not being used or what percentage was not available

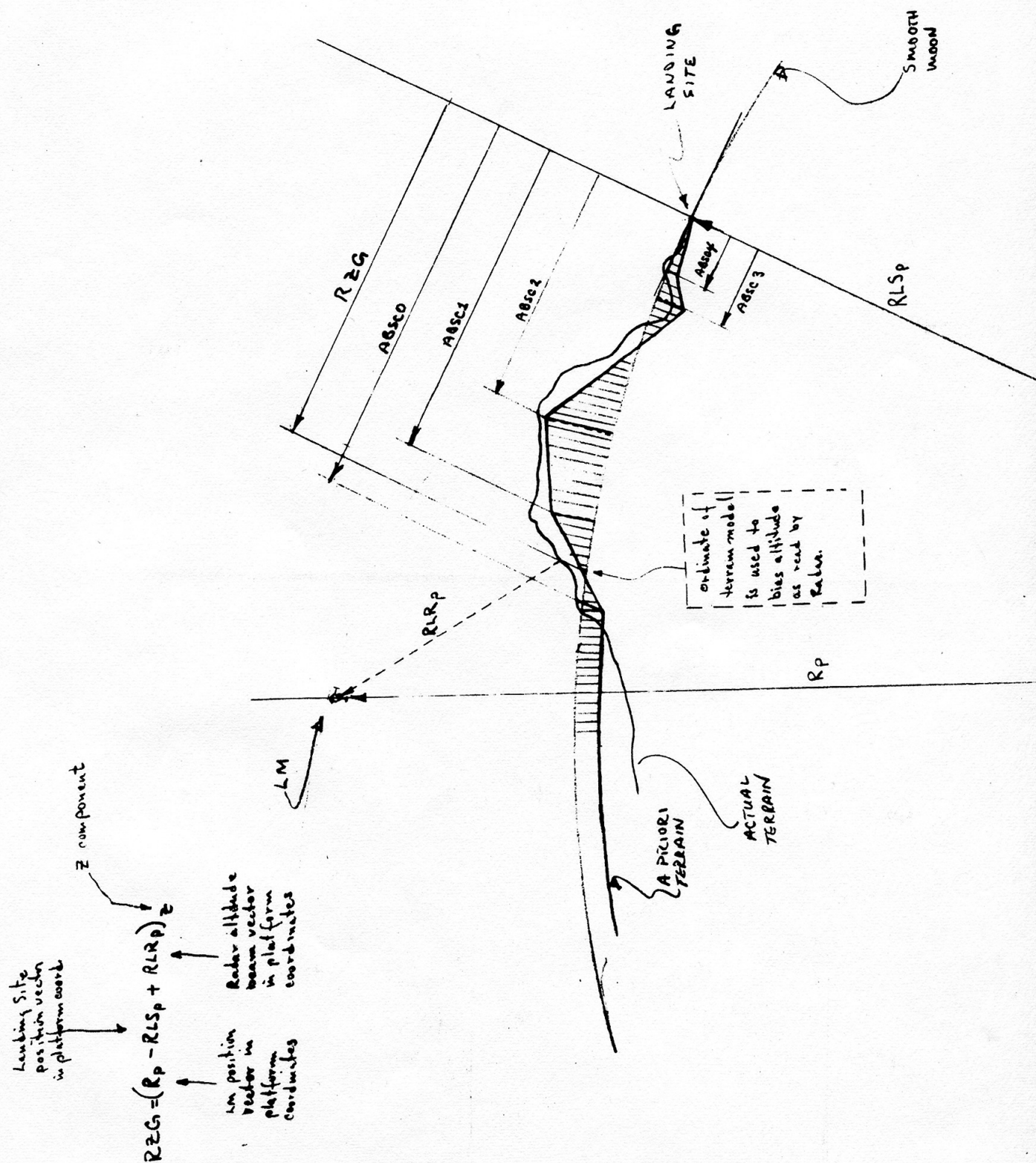
due to TLOSS. It was also thought possible that the post flight data could be used to calibrate LMS configuration time (presently it runs faster than the actual AGC). Two erasables were defined and are on all downlists (specified on PCR). SERV DURN (loc 1355) is loaded with the present LGC time (least significant half) just prior to the Average G Exit point (after navigation, prior to guidance). DUMLOOPS (loc 1356) is a counter which is incremented each time DUMMYJOB finds no job to be serviced -idle time. It will quit counting when a job is called, starting again when it is finished. Data will be published at a later date specifying the time between DUMLOOP increments.

McCoy

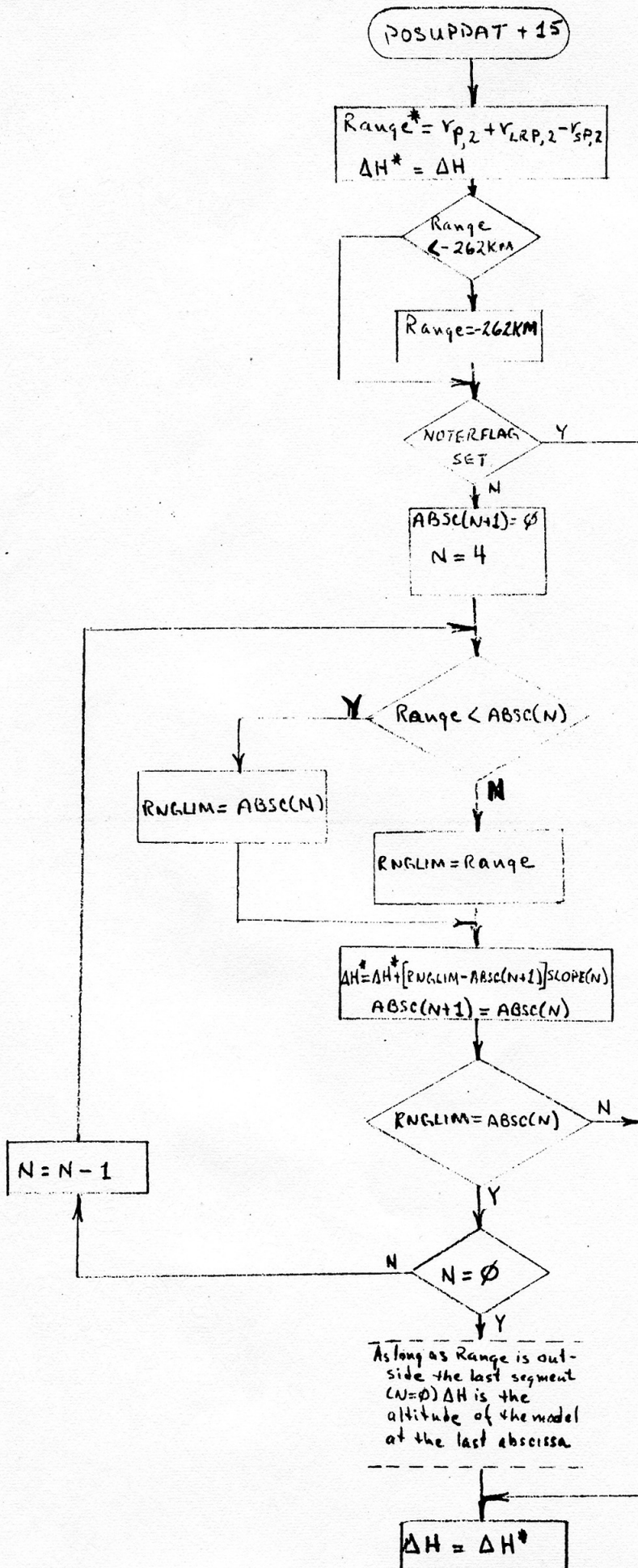
DATE: 5/13/70

SHEET

OF



A PRIORI TERRAIN MODEL



Range is a negative number equal to the z component in platform coord of the vector from the landing site to the point of intersection of the LR altitude beam with the lunar surface.

V66 or P66
Terminate terrain computations

Initialize for 5 possible passes; 4 denotes segment nearest the landing site

If the Range is not within the segment for this pass, ΔH^* is the altitude of the model at the abscissa. ΔH^* is then used to build the remaining segments

If the Range is within the segment for this pass, ΔH is the altitude of the model at this Range

WAS THIS THE LAST SEGMENT?

ADDITION TO LUMINARY MEMO #148

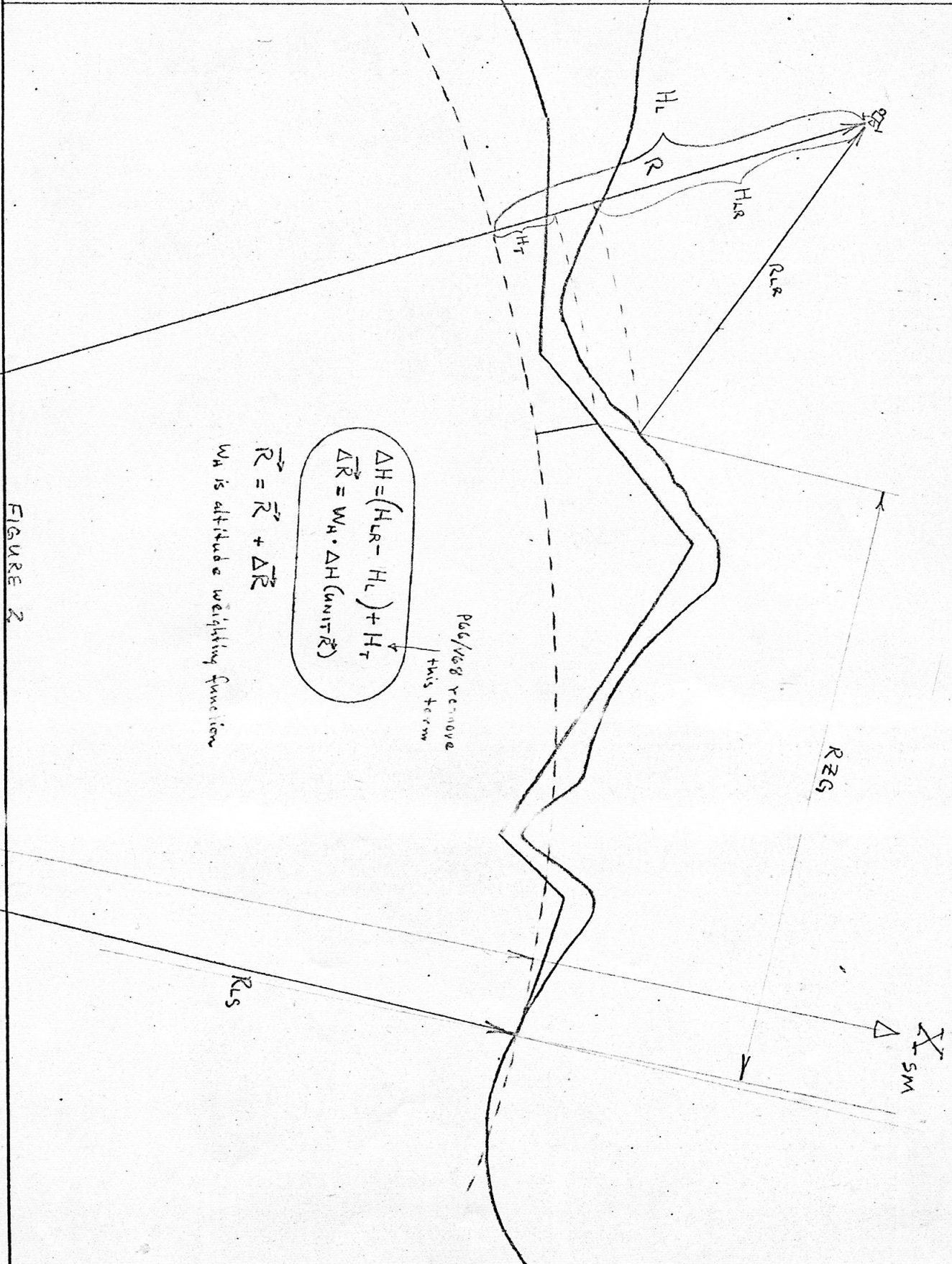
INSTRUMENTATION LABORATORY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
CAMBRIDGE, MASS.

PREPARED BY:

DATE:

SHEET

OF



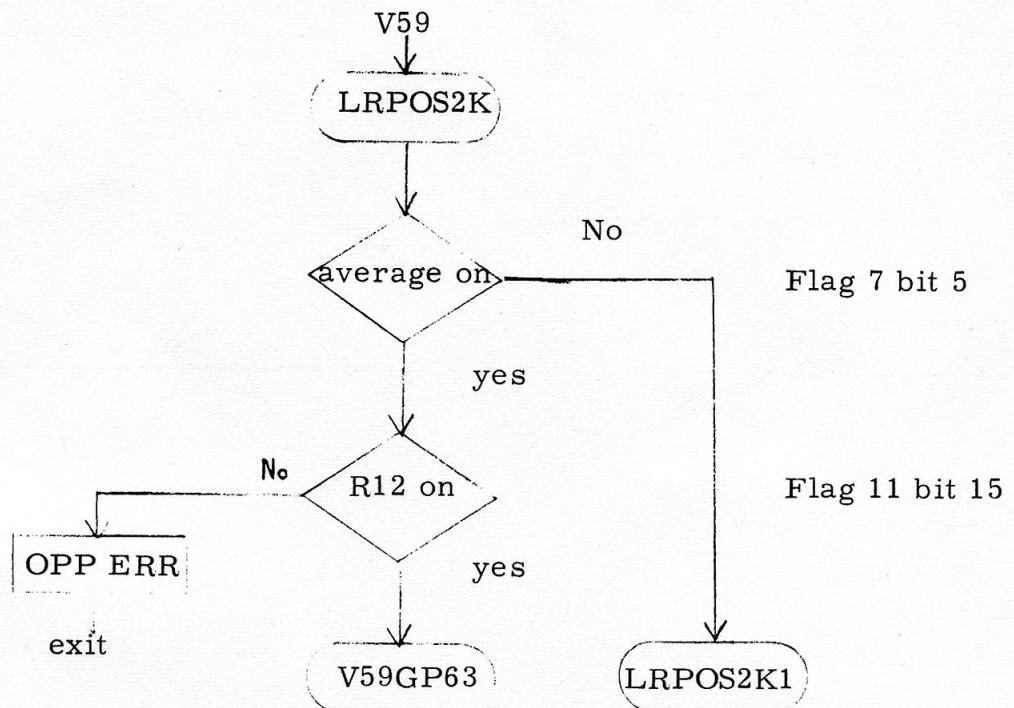
AnomalyImplementation/Comments

L-1C-01

It was found that a Restart during an EXTERNAL ΔV burn by P40 or P42 could cause a ΔV increment to be subtracted from VG again after the Restart recalled the steering routine S40.8. A Restart point was placed after the subtraction had been made.

L-1C-03

A coding error in V59 leadin caused the DAP estimated attitude errors to be placed on the FDAI needles as well as moving the LR antenna to position #2. It was rewritten as shown below:



Now, V59 can be used in P64 if desirable.

L-1C-04

See PCR 990.

L-1C-05

The computation of HCALC (a Double Precision word), the estimated altitude in a Descent or Ascent, did not assure sign agreement to both halves of the word. It caused the x-axis-override inhibit to occur at an altitude somewhat less (~ 26 kft) than the desired altitude (30 kft). A call to the SIGNAGREE was added in routine RVBOTH where HCALC is calculated for the altitude check.

L-1C-06

It was possible to not navigate some ΔV in P40, 42 or P63 if a V37 was used to terminate ullage or a DPS/APS guided burn because average G was turned off prior to allowing V37 to turn off ullage/the engine. In Luminary 1D a V37 turns off ullage/the engine immediately on finding Average-G on.

L-1C-08

A Restart while the DAP was in the manual rate command mode may cause 1) Temporary nulling of a Q or R axis manually commanded rate while the rotational hand controller is out of the detent position, or 2) Yaw to another attitude if the Restart occurs during rate command initialization.

To correct this, the desired CDU's are set equal to the actual CDU's each pass through Q/R axis in manual rate command mode and OURRCFLG is set after initialization of manual rate command mode is completed.

ACB's

L-11

When PCR 882 was implemented into Luminary 1C the Forward Velocity displayed in NOUN 60 was not computed when the MODE SELECT SW was in a position other than PGNCs. The check for the switch position was moved to a place in SPEEDRUN after Lateral and Forward Velocity are computed, thus, if the switch is in ^{AGS}~~ACC~~ or LDR, LATVEL and FORVEL will be computed for display and return is made to ALT/ALT RATE computations without sending LATVEL/FORVEL to the cross pointers.

L-12

The capability of a service routine (LONGCALL) was expanded to allow a call for a task located in a high super-bank (40-43). This was first implemented into COLOSSUS.

L-13

In the Ascent and Descent Programs, an interrupted display (such as V06N63) would cause an extra VAC area to be tied up when it is not really needed. If it was interrupted by an Extended Verb with display it would use 4 VAC areas. A routine (VACRLEAS) was written to change the next display job from one requiring a VAC area to one needing only a Core Set (12 registers instead of 42). The displays involved were the V06N63 displays in P12 and P63, the V06N64 displays in P64 and the N60 display in P66. This reduces the chance of receiving Executive storage overflow (31201, 31202) alarms.

L-14

Three fixed words were needed in bank 1 to implement PCR 872.2. It involved equating GENADR tags to fixed-fixed memory location equivalents.

L-15

Three fixed words were needed in bank 43 to implement PCR 990. Routine CLRADMOD was used to reset bits 14 and 10 of RADMODES which was done previously by 4 instructions. Redundant coding of resetting these bits in RRDESEND was deleted (same 4 instructions above to reset bits 14 and 10 had been followed by a TC CLRADMOD).

L-16

It was found in Luminary 1C a possible indeterminate transfer could occur if the TLOSS was high enough in P64 to cause a 1201 or 1202 alarm immediately prior to P66 entrance, occurring during the throttle routine. The problem had been caused by two programs using BANKCALL, the former destroying the return of the latter. A POSTJUMP and associated return interface replaced P66's BANKCALL to the throttle routine.

L-17

A Restart during a DPS throttle recovery caused the throttle commands to the DECA to be terminated because the Restart logic in STARTSUB2 "zeroed" bit 4 of channel 14 (Thrust Drive Enable). STARTSUB2 was changed to prevent the zeroing of this bit. Also, if a Restart occurred after the throttle pulses had been started but before the next phase change (after FINDCDUW) these pulses could be sent twice. A phase change (TC FASTCHNG) was added just after the return from throttle and just prior to FINDCDUW. A PCN 1043 was written to supercede this ACB since it was found after release that GSOP Section 2 was affected in a minute way. A statement was made that a Restart zeros all but bit 6 of channel 14.

L-18

Late changes were made to the Luminary 1C rope which were implemented at the same time AUTOP66 was crowned. One involved improving the logic on overflow checks in Lunar Landing in the Guidance Equations. It was found to be better to skip guidance commands if overflow occurred, regardless of the STEERSW. Another was a logic change in the same area (STEER?): remove the Attitude Hold Check for a decision to do a STOPRATE (tell the DAP to stop all attitude rates). There could be a situation of just switching PGNCs control mode from AUTO to Att Hold between FINDCDUW and the next pass through STEER?. The stoprate would then be bypassed unintentionally.

L-19

Don Eyles thought of an ingenious way of reducing duty cycle time (^{4%}~~by as~~) in the very busy P66. By adding a few instructions prior to QUICKTRIG (CDUSPOT = CDU), he used QUICKTRIG and *NBSM* in the P66 VERTICAL computations instead of the CDU*NBSM routine. Both methods are the same, transforming UNITX vector from NB to SM coordinates.

- L-20 Spelling of NEGORKP (an unreferenced erasable) and an insignificant card punch error for NOUN 60 were corrected.
- L-22 The setting and resetting of the R04 flag in R65 was deleted; it had prevented the 521 alarm which was eliminated by PCR 979.
- L-23 EBANKS 2 and 4 contained some erasable assignments that were not being used. Their tags were removed so that the locations may be available for assignment. They were W.IND1 (loc 1257), VACX, Y, Z (locs E4, 1537, 41, 43).
- L-24 EBANK 7 also contained some erasable assignments that shared unnecessarily with RTARG. ZERLINA, ELVIRA, AZINCR1 and ELINCR1 were moved from E7, 1443-46 to E7, 1644-47 replacing their dummy erasables. Other erasables VDGVERT, NIGNLOOP, and NGUIDSUB (E7, 1644-47) used to share with the above dummies, now share with ZERLINA, ELVIRA, AZINCR1 and ELINCR1.
- L-25 R. Covelli found that the Master Ignition Routine (BURN BABY, BURN) could be used by an erasable program (e. g. LM DEORBIT Erasable Program) if some instructions addressing fixed memory were changed to be able to address erasable memory also. For example
- | | |
|-------|-------|
| INDEX | WHICH |
| TCF | 12 |
- is used to transfer control to a location specified by the 12th location of a table (each program has its own table specified by WHICH). If the TCF (Transfer Control to Fixed memory) were to be changed to TC (Transfer Control to either Fixed or erasable) a table such as that used for P40, 41 or 42 could be placed into erasable memory and program flow could

transfer between an erasable memory program and the
Master Ignition Routine.

